CLAIMS

We Claim:

1. An electromagnetic chip with individually addressable micro-magnetic units comprising:

a substrate;

a plurality of micro-electromagnetic units on the substrate, each unit structured to produce a magnetic field upon application electric current thereto; and

means for selectively applying an electric current to any one of the plurality of units to produce a magnetic field therein.

2. The electromagnetic chip of Claim 1, wherein each micro-electromagnetic unit comprises a magnetic core on the substrate and means for conducting an electric current about the magnetic core.

3. The electromagnetic chip of Claim 2, wherein means for conducting an electric current about the magnetic core comprises single or multiple loops of electric conductive traces around the magnetic core.

4. The electromagnetic chip of Claim 3, wherein the loops of electric conductive traces are of a circular, a square, an elliptical, a triangular, a spiral, or a squared-spiral shape.

5. The electromagnetic chip of Claim 3, further comprising means for modulating a magnitude and a polarity of the electric current selectively applied to any one of the plurality of units.

6. The electromagnetic chip of Claim 2, wherein the magnetic core comprises a ferromagnetic material or a ferrimagnetic material.

7. The electromagnetic chip of Claim 1, wherein the micro-electromagnetic units are arranged on the substrate in a regular, repetitive pattern with equal distances between neighboring units.

8. The electromagnetic chip of Claim 1, wherein the micro-electromagnetic units have dimensions of width and length ranging between 0.1 micrometer and 1 cm.

9. The electromagnetic chip of Claim 1, wherein the means for selectively applying comprises conductive connections between each micro-electromagnetic unit and a source of electric current and switch means for alternately interrupting and establishing a flow of electric current through the conductive connections.

10. The electromagnetic chip of Claim 9, wherein the switch means are either mechanical or electronic switches.

11. An electromagnetic chip with individually addressable micro-magnetic units comprising:

a substrate;

a plurality of micro-electromagnetic units on the substrate, each unit structured to produce a magnetic field upon application electric current thereto;

means for selectively applying an electric current to any one of the plurality of units to produce a magnetic field therein; and

a functional layer for immobilizing ligand molecules.

12. The electromagnetic chip of Claim 11, wherein the functional layer is selected from the group consisting of a hydrophilic molecular monolayer, a hydrophilic molecular monolayer with functional groups, a hydrophobic molecular monolayer, a hydrophobic molecular monolayer with functional groups, a hydrophilic membrane, a hydrophilic membrane with functional groups, a hydrophobic membrane, a hydrophobic membrane with functional groups, a hydrophilic gel, a hydrophilic gel with functional groups, a hydrophobic gel, a hydrophobic gel with functional groups, a porous material, a porous material with functional groups, a non-porous material and a non-porous material with functional groups.

13. The electromagnetic chip of Claim 12, wherein the functional groups are selected from the group consisting of aldehydes, carbodiimides, succinimydyl esters, antibodies, receptors, and lectins.

14. An electromagnetic chip with individually addressable micro-magnetic units comprising:

a substrate;

a plurality of micro-electromagnetic units on the substrate, each unit structured to produce a magnetic field upon application electric current thereto;

means for selectively applying an electric current to any one of the plurality of units to produce a magnetic field therein;

a functional layer for immobilizing ligand molecules; and

ligand molecules immobilized by the functional layer.

15. The electromagnetic chip of Claim 14, wherein the ligand molecules are selected from the group consisting of oligonucleotides, DNA molecules, RNA molecules, proteins, antibodies, lectins, and receptor molecules.

16. An electromagnetic chip having an array of individually addressable micro-electromagnetic units (10) comprising:

a substrate (16);

an array of cavities (22) in the substrate (16), arranged in columns and rows, each cavity containing a ferromagnetic core (26);

a first layer of conductive traces (18), each separate trace of said first layer of conductive traces running adjacent to one of the columns;

a second layer of conductive traces (30) insulated from the first layer of conductive traces (18) with each of said second layer of conductive traces (30) perpendicular to said first layer of conductive traces and running adjacent to one of the rows.

17. The electromagnetic chip of Claim 16, wherein a first layer of insulating material separates the first layer of conductive traces from the second layer of conductive traces.

18. The electromagnetic chip of Claim 17, wherein the material of said first insulating layer is selected from the group consisting of silicon dioxide, silicon nitride, plastic, glass, ceramic, photoresist and rubber.

19. The electromagnetic chip of Claim 16, wherein a second layer of insulating material is deposited on a top surface of the second layer of conductive traces and on a top surface of said ferromagnetic cores.

20. The electromagnetic chip of Claim 19, wherein the material of said second insulating layer is selected from the group consisting of silicon dioxide, silicon nitride, plastic, glass, ceramic, photoresist and rubber.

21. The electromagnetic chip of Claim 16 further comprising an additional layer of conductive traces, each of said set of conductive traces running adjacent to one of the columns and insulated from other layers of conductive traces.

22. The electromagnetic chip of Claim 16 further comprising a further layer of conductive traces, each of said layer of conductive traces running adjacent to one of the rows and insulated from other layers of conductive traces.

23. The electromagnetic chip of Claim 16, wherein the substrate is a material selected from the group consisting of silicon, glass, ceramic, silicon dioxide and plastic.

24. The electromagnetic chip of Claim 16, wherein the conductive traces are composed of a material is selected from the group consisting of aluminum, gold, silver, tin, copper, platinum, palladium, carbon, and semiconductor materials.

25. The electromagnetic chip of Claim 16 further comprising a functional layer for binding ligands.

26. The electromagnetic chip of Claim 25, wherein the functional layer is selected from the group consisting of a hydrophilic molecular monolayer, a hydrophilic molecular monolayer with functional groups, a hydrophobic molecular monolayer, a hydrophobic molecular monolayer with functional groups, a hydrophilic membrane, a hydrophilic membrane with functional groups, a hydrophobic membrane, a hydrophobic membrane with functional groups, a hydrophilic gel, a hydrophilic gel with functional groups, a hydrophobic gel, a hydrophobic gel with functional groups, a porous material, a porous material with functional groups, a non-porous material and a non-porous material with functional groups.

27. The electromagnetic chip of Claim 26, wherein the functional groups are selected from the group consisting of aldehydes, carbodiimides, succinimydyl esters, antibodies, receptors, and lectins.

28. The electromagnetic chip of Claim 16, further comprising a fluidic chamber for bringing liquids into contact with the array.

29. An electromagnetic chip having an array of individually addressable micro-electromagnetic units (10) comprising:

a substrate (16);

an array of cavities (22) in the substrate (16), arranged in columns and rows, each cavity containing a ferromagnetic core (26); and

a first layer of conductive traces (30'), each of said first layer of conductive traces extending at least 90° around one of the ferromagnetic cores.

30. The electromagnetic chip of Claim 29 further comprising an additional layer of conductive traces, each of said set of additional conductive traces extending at least 90° around one of the ferromagnetic cores and being separated from said first set of conductive traces by an insulating layer penetrated by a vertical conductive connection between traces of said first layer and traces of said additional layer.

31. The electromagnetic chip of Claim 30, wherein a first layer of insulating material separates the first layer of conductive traces from the additional layer of conductive traces.

32. The electromagnetic chip of Claim 31, wherein the material of said first insulating layer is selected from the group consisting of silicon dioxide, silicon nitride, plastic, glass, ceramic, photoresist and rubber.

33. The electromagnetic chip of Claim 29, wherein a second layer of insulating material is deposited on a top surface of the array.

34. The electromagnetic chip of Claim 33, wherein the material of said second insulating layer is selected from the group consisting of silicon dioxide, silicon nitride, plastic, glass, ceramic, photoresist and rubber.

35. The electromagnetic chip of Claim 29 further comprising a functional layer for binding ligands.

36. The electromagnetic chip of Claim 35, wherein the functional layer is selected from the group consisting of a hydrophilic molecular monolayer, a hydrophilic molecular monolayer with functional groups, a hydrophobic molecular monolayer, a hydrophobic molecular monolayer with functional groups, a hydrophilic membrane, a hydrophilic membrane with functional groups, a hydrophobic membrane, a hydrophobic membrane with functional groups, a hydrophilic gel, a hydrophilic gel with functional groups, a hydrophobic gel, a hydrophobic gel with functional groups, a porous material, a porous material with functional groups, a non-porous material and a non-porous material with functional groups.

37. The electromagnetic chip of Claim 36, wherein the functional groups are selected from the group consisting of aldehydes, carbodiimides, succinimydyl esters, antibodies, receptors, and lectins.

38. The electromagnetic chip of Claim 29, wherein the substrate is a material selected from the group consisting of silicon, glass, ceramic, silicon dioxide and plastic.

39. The electromagnetic chip of Claim 29, wherein the conductive traces are composed of a material is selected from the group consisting of aluminum, gold, silver, tin, copper, platinum, palladium, carbon, and semiconductor materials.

40. The electromagnetic chip of Claim 29 further comprising a fluidic chamber for bringing liquids into contact with the chip.

41. A method for directing reactions between ligand and target molecules, comprising the steps of:

providing a unit having a plurality of individually addressable micro-electromagnetic cores;

forming a functional layer for immobilizing ligand molecules above said cores;

modifying ligand molecules to make the ligand molecules positionable by magnetic fields;

disposing a solution containing the modified ligand molecules on the functional layer;

creating a pattern of immobilized ligand molecules by selectively energizing magnetic cores to form magnetic fields which position said ligand molecules at predetermined locations where said ligand molecules become immobilized on the functional layer;

modifying target molecules to make the target molecules positionable by magnetic fields;

disposing a solution containing the modified target molecules on the pattern of immobilized ligand molecules; and

selectively energizing magnetic cores to form magnetic fields which position the modified target molecules in juxtaposition to predetermined immobilized ligand molecules allowing a reaction between predetermined target molecules and predetermined ligand molecules.

42. The method of Claim 41 further comprising a step of detecting the reaction between the predetermined target molecules and the predetermined ligand molecules.

43. The method of Claim 42, wherein the step of detecting the reaction comprises optical detection.

44. The method of Claim 41, wherein the functional layer is selected from the group consisting of a hydrophilic molecular monolayer, a hydrophilic molecular monolayer with functional groups, a hydrophobic molecular monolayer, a hydrophobic molecular monolayer with functional groups, a hydrophilic membrane, a hydrophilic membrane with functional groups, a hydrophobic membrane, a hydrophobic membrane with functional groups, a hydrophilic gel, a hydrophilic gel with functional groups, a hydrophobic gel, a hydrophobic gel with functional groups, a porous material, a porous material with functional groups, a non-porous material and a non-porous material with functional groups.

45. The method of Claim 44, wherein the functional groups are selected from the group consisting of aldehydes, carbodiimides, succinimydyl esters, antibodies, receptors, and lectins.

46. The method of Claim 41, wherein the step of modifying ligand molecules comprises linking the ligand molecules to magnetic material.

47. The method of Claim 46, wherein the step linking the ligand molecules to magnetic material is achieved by a cleavable linker.

48. The method of Claim 47, wherein the cleavable linker is cleavable by one of light, heat, enzymatic activity or chemical reaction.

49. The method of Claim 46, wherein linking the ligand molecule to magnetic material is achieved by a covalent bond or biological affinity.

50. The method of Claim 49, wherein biological affinity is selected from the group consisting of antibody-antigen affinity, lectin-hapten affinity, and receptor-ligand affinity.

51. The method of Claim 41, wherein the step of modifying target molecules comprises linking the target molecules to magnetic material.

52. The method of Claim 51, wherein the step of linking the target molecules to magnetic material is achieved by a cleavable linker.

53. The method of Claim 52, wherein the cleavable linker is cleavable by one of light, heat, enzymatic activity or chemical reaction.

54. The method of Claim 51, wherein linking the target molecule to magnetic material is achieved by a covalent bond or biological affinity.

55. The method of Claim 54, wherein biological affinity is selected from the group consisting of antibody-antigen affinity, lectin-hapten affinity, and receptor-ligand affinity.

56. The method of Claim 41, wherein the target molecule or the ligand molecule is separated from the magnetic material by cleaving the cleavable linker.

57. The method of Claim 56, wherein the separated magnetic material is removed by a magnetic field or by a fluidic wash.

58. The method of Claim 41, wherein the modification of the ligand molecules comprises mixing a solution of the ligand molecules with magnetic material, and freezing droplets of ligand molecules mixed with magnetic material to form small solid magnetic particles.

59. The method of Claim 58 further comprising the step of using magnetic dispensers to position the small solid magnetic particles on the unit.

60. The method of Claim 41, wherein said ligand and said target molecules are either biological molecules, chemical reagents or pharmaceutical molecules.

61. The method of Claim 41, wherein said ligand and said target molecules comprise nucleic acid molecules.

62. The method of Claim 41, wherein said ligand and said target molecules comprise antibodies and antigens.

63. A method for manipulating magnetic particles, comprising the steps of:

providing an electromagnetic chip having a plurality of individually addressable micro-electromagnetic units;

placing magnetic particles onto an exposed surface of the chip; and

modulating electric currents applied to each micro-electromagnetic unit so as to change the magnetic field distribution over the chip surface, thereby altering magnetic forces acting on the magnetic particles

64. The method of Claim 63, wherein magnetically-modified biomolecules/particles comprise biomolecules/particles linked to magnetic materials.

65. The method of Claim 64, wherein the link of biomolecules/particles to magnetic materials is through linkage molecules, a covalent bond or biological affinity.

66. The method of Claim 64, wherein biomolecules/particles are DNA molecules, cDNA segments, protein molecules, cell particles.